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Research Article

A Study on Real-time voice information equipment and management system research in smart office environment

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Abstract

Background/Objectives: This paper aims to "develop voice information protection equipment and management system in smart office environment" to prevent voice recording and leakage in the most advanced device environment.

Methods/Statistical analysis: The operation status of the voice information protection equipment is monitored and the noise output strength of each port is displayed in the independent voice-like noise for each output port in the proposed 20 Hz ~ 20 KHz frequency range. We would like to propose a management system linkage function and monitoring system in the master volume and volume display window such as equalizer control.

Findings: In this study, a management system application for voice recording prevention was proposed. Through this system, when a failure occurs, alarm and warning functions, equipment operation status, failure-related status and report output are possible. By supporting the monitoring function of the speaker and the voice leakage prevention vibrator in the recording prevention function, social conflicts about voice recording can be resolved.

Improvements/Applications: The management system of the voice information protection equipment monitors the condition of the equipment, whether the vibrator and speaker normally operate in real time, and allows the administrator to easily control each function.

Keywords**:** voice security, loss prevation, Prevention of recording, security, management system

1. Introduction

With the commercialization of 5G mobile communication services today, the use of smartphones has become popular. 5G can be accessed at a speed of up to 20 times faster than

previous LTE-class 4G and can transmit not only high-quality content but also large-capacity content such as VR in real time. In addition, the application of 5G to infrastructure such as artificial intelligence and smart cities is expected to bring many changes in our lives, such as collecting/analyzing real-time data to improve the quality of life. The development of the smart device industry of information and communication technology provides the overall development and convenience of society, such as the daily life of individuals, the country, and industry, but as a side effect, the problem of illegal voice recording and leakage of voice information, which are national, industrial, and personal, are seriously raised as a side effect. Has become. The concept of voice information protection equipment blocks illegal recording from smart devices (smartphones, micro-recorders) for major conferences and confidential voice information, and completely blocks the leakage of important voice information from outside by eavesdroppers. It is an integrated solution that provides a management system function that checks and controls the status of multiple voice information protection equipment in real time. Recently, it has become a national and social problem due to illegal disclosure of recorded files, and we would like to propose a security system for the leakage of national, social and personal information[1].

2. Materials and Methods

It is a system that records conversations of people in a smart office environment or protects against leaks and recordings in real time when attempting to tap through an external wiretapping device. As multiple equipments are operated in a single institution, real-time control of users is required. Monitoring the operation status of voice information protection equipment and preventing noise emission and recording through the speaker-type vibrator port in independent voice-like noise (noise with a spectrum similar to voice) for each output port in the proposed 20 Hz to 20 KHz frequency range. I would like to propose a recording prevention function according to speaker output and a monitoring system and a management system linkage function such as master volume and volume display window, such as noise output strength and equalizer control for each port of recording prevention speaker/vibrator[2,3].

Voice information protection equipment is largely divided into a control unit, an ultrasonic/noise generation and output unit, a user matching unit, a power generation unit, and a vibrator state detection unit. The control unit uses the MSP430F1611 processor to design the AD conversion function, main memory, etc. using the circuit built into the MSP430F1611. The number of elements is reduced as much as possible, and the addition of unnecessary circuits and accuracy is suppressed compared to the use of an external AD conversion circuit.

A separate FPGA is implemented for equalizer control used in the ultrasonic/noise output unit and output on/off for audio AMP, and changes and controls the MSP430F1611 local bus signal to a signal suitable for other block control. The ultrasonic/noise generator generates voice-like noise using 25MHz ultrasonic generation or OP-AMP. The ultrasonic/noise output unit is designed to output to a sound-preventing speaker through the output of an ultrasonic signal equalizer, or to synthesize the output of the noise equalizer and an external sound source to output to a speaker and a vibrator.

The user matching unit displays the output strength of the oscillator Master Volume, the ultrasonic Master Volume, and the normal operation of each port using LEDs. Various control functions are displayed on the LCD in the form of a menu and the noise output is controlled by using the function buttons. The power generator receives AC power converted to DC18V using an adapter and converts it into power available for each device (+3.3V, +5V, -5V, +8V, +12V, -12V). In addition, it is designed to enable power ON/OFF by external remote control control.

The vibrator state detection unit is an external vibration detection module and detects the current flowing through the vibrator. It is designed so that the state of the vibrator can be transmitted to the user matching unit to determine whether or not there is a failure.

2.1. Embedded OS(F/W)

In Figure 1, the Embedded OS initializes and operates the processor and device driver when power is applied.

The OS is largely composed of a bootloader and a kernel. Bootloader is loaded from Flash into DRAM when power is applied from the processor, initializes the basic processor and basic devices, and loads the kernel into DRAM. The kernel provides an interface between hardware and application programs, and applications can manage and use resources from the hardware[4].

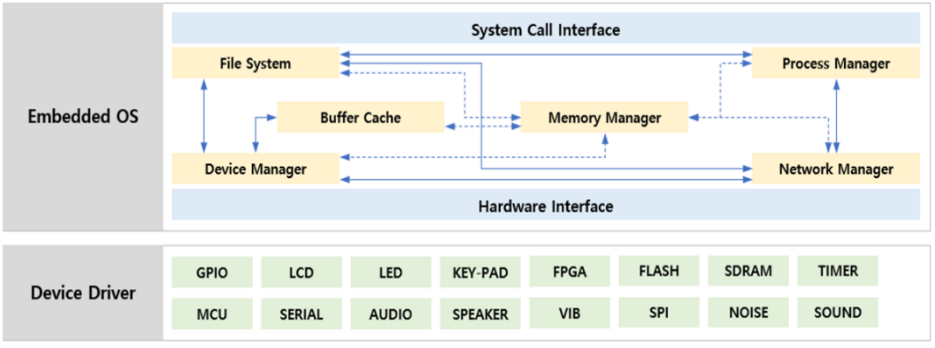

Figure 1. Configuration of voice information protection equipment

2.2. *Device Driver*

Interrupts are GPIO interrupts, timer interrupts, and ADC interrupts. GPIO interrupt is used when a menu related button is pressed through the FPGA. When the button is pressed for the first time, the value of the button is notified, and when the button is pressed continuously for a certain period of time, it is determined that the key is pressed again, and the same button value is suggested. Two timer interrupts are used, and a timer running at 50ms counts 1 second and 1 minute and blinks the LED. The 41.5μs timer is set to run ADC every time an interrupt occurs. This is developed to sample the analog waveform of the voice and vibration acceleration device at 24KHz[5]. LPF (Low Pass Filter) samples the voice signal and the vibration accelerator signal at 24KHz, and takes a 256-point FFT of the value stored in 8Khz, and the result is up to 4KHz. Therefore, it is developed to use a digital low pass filter to cut out the frequency components exceeding 4Khz. LPF uses Equation 1 below.

$$K = 10$$

$$y(n) = y[n-1] + (x[n] - x[n-K])\ /K \quad (1)$$

AGC (Automatic Gain Control) control finds the largest value among the results of the ADC in units of 256 points and compares it with the threshold value, and if it is small, it gradually increases the gain, and if it is large, it gradually decreases the gain and adjusts it to a level similar to the threshold value. In channel AMP and equalizer control, AMP is designed to be controlled by DIO and equalizer is controlled by SPI interface. Equalizer can be set by first transmitting the LSB with SPI for 8 bits of address and 40 bits of data. Since the volume control of the equalizer can be adjusted from 0 to -76dB in 1 step increments, create a menu to adjust the volume from -40 to 0dB in 40 steps.

Equalizer can be controlled from -10 to 10dB in 2 steps for each band, so the menu is configured so that it can be controlled in 10 steps. However, since the recording prevention speaker uses an ultrasonic frequency of 25kHz or higher, the setting of the 100Hz and 1kHz bands is disabled, and the menu is configured so that only the bands of 10kHz or higher can control up to -10 ~ 10dB in 2 steps.

2.3. *Equipment control and information management function*

In the equipment control function, the operation setting and output level of each port are set. Operation setting and output level are set through the LCD and buttons of the equipment, and set upon request from a remote control system. The functions of equipment setting information are as follows. Recording-prevention speaker/vibrator port ON/OFF, master output level setting of all ports, recording-prevention speaker/vibrator port-specific output level setting, recording-prevention speaker/vibrator port-specific equalizer adjustment and initializing the equipment settings.

Equipment information management manages basic equipment information (software version, company name), equipment monitoring information, equipment control information, and saves and manages it in Flash.

When power is applied, it is read from Flash, managed in DRAM, and output ON/OFF and output level of the recording prevention speaker/vibrator port are set. The setting information of the recording prevention speaker/vibrator port can be changed from the front panel or a remote management system, and this information is saved back to Flash.

2.4. *Management system linkage function*

It is a function to communicate with a remote management system, and it is a function to control the status and control of the overall equipment remotely. When communicating between the management system and the system, the HTTPS (Hypertext Transfer Protocol over Secure Socket Layer) protocol protects data between systems. HTTPS is a method of encrypting session data through SSL or TLS protocol during socket communication. The data follows the JSON format. The SSL/TLS protocol is implemented with the Wolfssl library. Wolfssl provides a compact and portable built-in SSL/TLS library targeted at the use of embedded system developers.

3. Results and Discussion

3.1. Development of voice information protection equipment for smart office

The voice information protection equipment performs the function of preventing recording and leakage of voice information through ultrasonic waves, audible noise emission, and audible frequency vibration. The signal source generated through the ultrasonic wave and noise generator is filtered to remove the voice band, and after passing the ultrasonic band, equalization and output are controlled in the sound process.

It is amplified by a sound amplifier and radiated to a free space using a recording prevention speaker to block recording. The pink noise generated through the noise generator is synthesized by external noise through deceptive jamming, and the synthesized noise is equalized to the audio processor. Figure 2 is amplified by the audio amplifier to prevent leakage through audible vibration [6, 7].

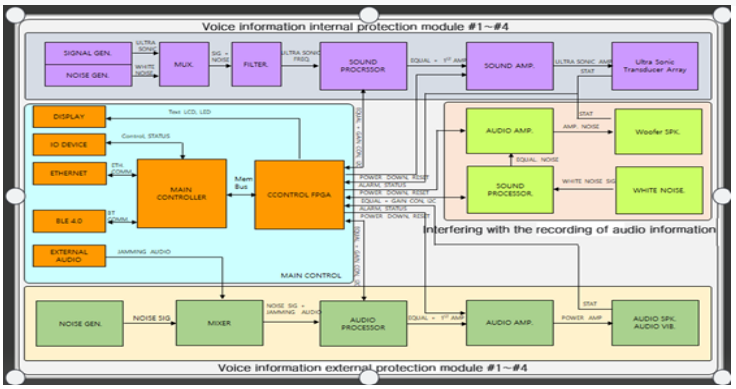

Figure 2. Voice information protection equipment development configuration

Noise Gen generates white noise to prevent leakage of external voice information, and implements internal voice information recording prevention function by muxing SIGNAL Gen and Noise Gen. It is implemented to provide convenience of installation by developing a recording prevention module as an internal/external type. Each of the internal voice recording prevention function and the external voice information leakage function are developed in the form of modules, and are applied variably according to the user environment[8].

3.2. Control processor

In the composition of the voice information protection equipment, it is a block that performs the functions of controlling the main elements, managing the state, and linking the management system. Control process operation uses Cortex-M4, 180MHz, 1.7V~ 3.6V operating voltage and internal memory: 2MB Flash, 256KB SRAM, 4KB BPSRAM, 12BIT ADC 3 Port, DAC 2 Port, FMC. For external memory bus implementation and communication, 3Port I2C, 6 Port SPI, 2 PorT I2S, 8 Port USART/UART, USB OTG Fs, 2 Port CAN, 1 Port SAI, 1Port Ethernet, SDIO/MMC storage device and LCD-TFT Display Interface It consists of[10].

3.3. Ultrasonic synthesis

Figure 3 is controlled through the SPI interface from the control processor and performs the function of generating 25kHz ultrasonic waves.

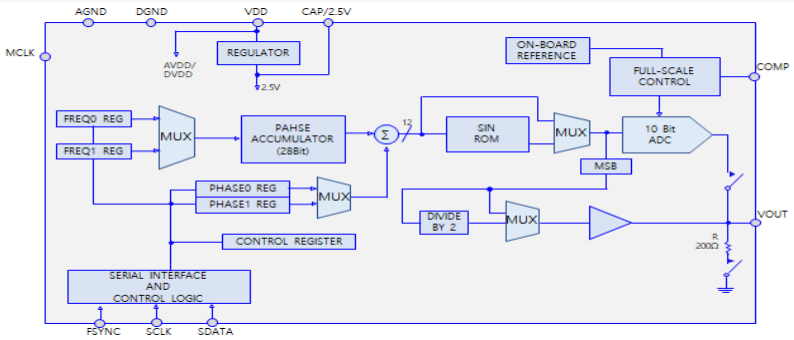

Figure 3. Diagram of ultrasonic generation

The operation of the ultrasonicator uses a 3.3V low voltage operation, a 2.65mW low power device, and uses a 0.1Hz to 25MHz reference clock at an output frequency of 0 to 12.5MHz and a resolution of 28 BIT. Sine wave, triangle wave, and square wave are output as waveforms and SPI control is performed[6, 9].

3.4. Signal frequency band control

It controls through the I2C interface from the control processor, and controls the ultrasonic band output to prevent recording. Controls the output of the audio band for recording interference using white noise. In order to prevent the leakage of voice information, the voice band output for driving the vibrator of the voice band is controlled[11].

3.5. Signal output strength control

AMP is cut off in case of output error or recording prevention module error through the IO interface from the control processor. It is a high-efficiency Class-D amplifier that provides 12W output and performs functions of driving an ultrasonic generator, driving a white noise generating speaker, and driving a voice vibrator[12].

4. Experiment result

4.1. Management system for smart office

The management system of the voice information protection equipment monitors the condition of the equipment, whether the vibrator and speaker are operating normally, and allows the administrator to easily control each function. In addition, it is developed to enable continuous monitoring by collecting and controlling information on connection, failure, and change history of equipment. Figure 4 shows the FPGA and ultrasonic/noise generation and output matching. It consists of 16 ports of maximum vibrator or 16 ports of ultrasonic waves and 2 ports of speaker.

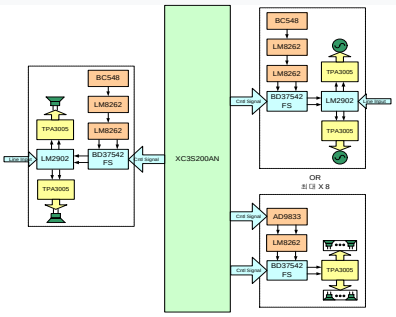

Figure 4. Ultrasound/noise generation and matching between outputs

4.1.1. Ultrasonic generation/output

As shown in Figure 5, the ultrasonic signal generator generates a 25KHz ultrasonic signal, which is an ultrasonic frequency band, according to the SPI control from the FPGA. The 25KHz ultrasonic signal is inverted and amplified through the LM8262 AMP and input to the equalizer.

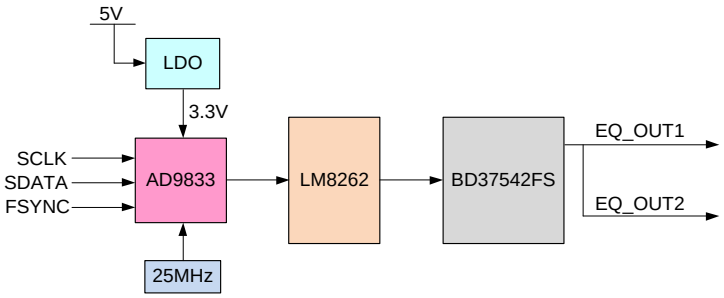

Figure 5. Ultrasonic signal generator

The equalizer in Figure 6 controls the output level of each ultrasonic 25KHz input through two channels, and is implemented with the BD37542FS Sound Processor with Built-in 3-band Equalizer Control System. The gain can be adjusted from -5dB to 0dB in 1dB steps.

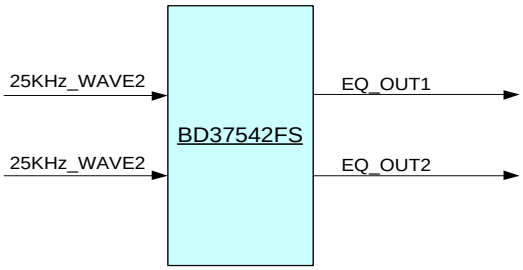

Figure 6. Equalizer

The Audio AMP in Figure 7 was designed with TPA3005D2, a Class-D class Modulation AMP. TPA3005D2 Audio AMP can output up to 6W based on 8Ω load, 12V, and provides more than 90% efficiency.

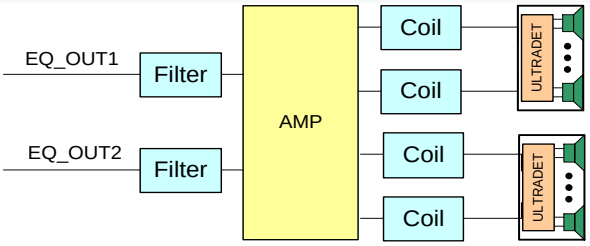

Figure 7. Audio AMP

4.1.2. Vibrator condition monitoring unit

In Figure 8, the vibrator status signal connection of the VIBDOT board receives the vibrator status detection signal and control signal from the FPGA and controls the vibrator output on/off from the VIBDOT board. The sensing signal and the status signal are only received from the vibration sensing module and transmitted to the FPGA.

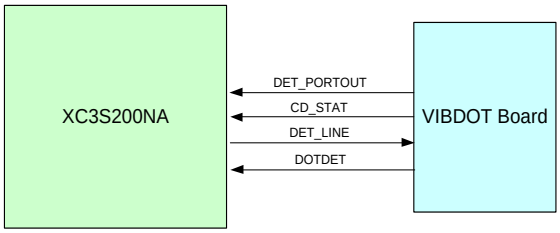

Figure 8. VIBDOT board vibrator status signal connection

The vibration detection module in Fig. 9 vibrates the vibrator by receiving the vibrator output signal from the VIBDOT board. This output signal is sensed by current and, if it exceeds a certain value, transmits a normal signal to the VIBDOT board. The status of the vibration detection module is also transmitted to the VIBDOT board, so that it is possible to check whether the vibration detection module is properly connected to the cable.

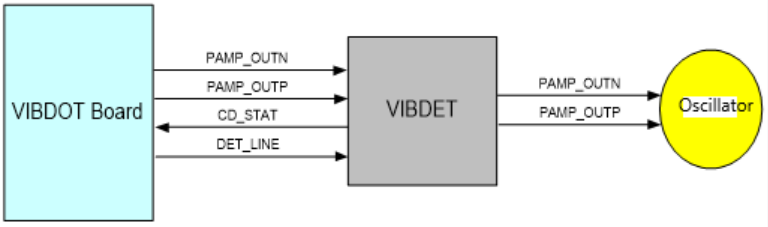

Figure 9. Vibration detection module

4.1.3. Recording prevention speaker condition monitoring unit

ULTRADOT board recording prevention speaker status signal connection in Figure 10: Receives the recording prevention speaker status detection signal and control signal from the FPGA, and controls the recording prevention speaker output ON/OFF from the ULTRADOT board. The sensing signal and the status signal are only received from the ultrasonic sensing board and transmitted to the FPGA.

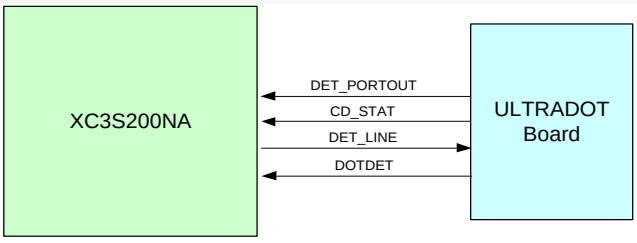

Figure 10. ULTRADOT board recording prevention speaker status signal connection

The recording-prevention speaker in Figure 11 receives the ultrasonic output signal from the ULTRADOT board and operates the ultrasonic transducer. It senses the current and transmits a normal signal to the ULTRADOT board if it is above a certain value. The status of the ultrasonic

detection board is also transmitted to the ULTRADOT board, so it is possible to check whether the recording-preventing speaker is properly connected to the cable.

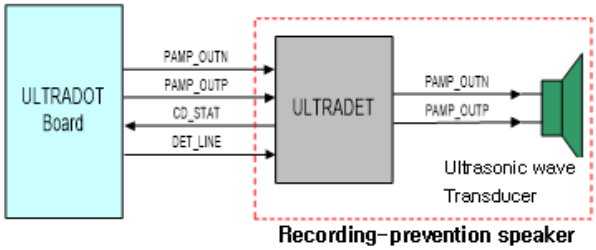

Figure 11. Record-proof speaker

4.2. Equipment control and connection management

Check the connection status of the management system for each device, and set the output level of the recording prevention speaker/vibrator and the equalizer output value in the remote management system. The setting information of the voice-preventing speaker/vibrator can be initialized to the default setting value at the time of initialization. In case of network error between the device and the management system, the network status can be checked through the PING/TraceRT command. Equipment control and connection management consists of terminal connection status, terminal failure status, terminal control, and system resource status.

4.2.1. Terminal connection status

Figure 12 provides a function that can grasp the terminal's connection status at a glance. You can check the basic and connection information of all currently registered devices.

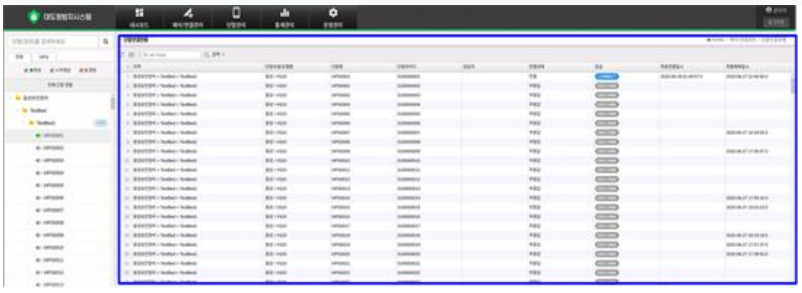

Figure 12. Terminal connection status

4.2.2. Device failure status

Figure 13 provides a function to grasp the fault status of the terminal at a glance. You can check the currently faulty equipment in the form of a list.

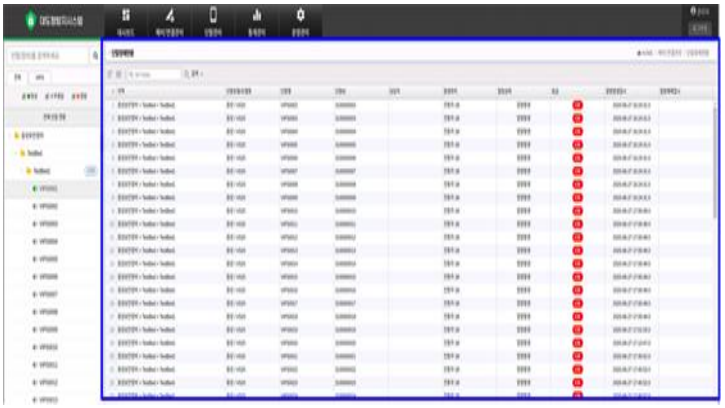

Figure 13. Device failure status

4.2.3. Terminal control

Figure 14 provides the function to change the terminal configuration or control the operation. As shown in the picture of "Voice Information Protection Equipment Control Window" at the bottom, A. Change confirmation, B. Reboot, C. Initialization, D. (vibrator) Master Volume, E.VOX, F.Buzzer, G. Synchronization cycle, H .Ultrasonic speaker Master Volume, I. Speaker, J. Vibrator and speaker setting functions are provided.

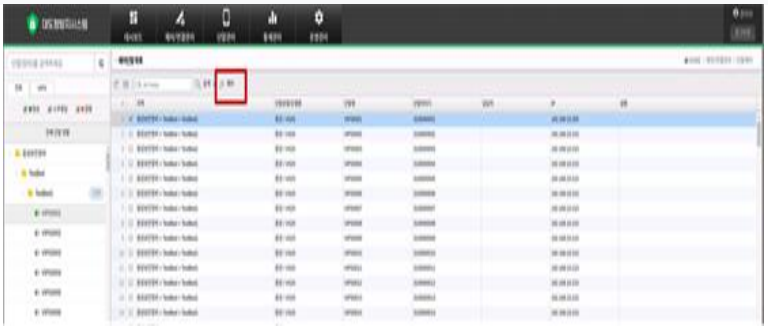

Figure 14. List of equipment for control

Figure 15 is a picture of the MAIN Board assembly result. Figure 16 prevents the leakage of voice information by connecting a vibrator to prevent eavesdropping on voice information and a speaker to prevent recording. Excellent performance was recognized by requesting a performance test from an accredited certification testing institute for the loudspeaker failure notification and the vibrator failure notification at the time of failure and the control recognition time for the output strength of the vibrator and the alarm notification time when a failure occurs.

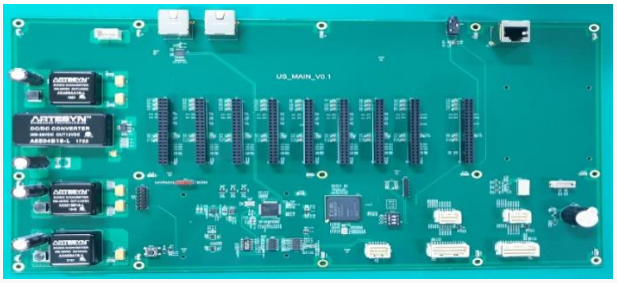

Figure 15. MAIN Board PBA assembly picture

Figure 16. Eavesdropping prevention vibrator connection and recording prevention speaker connection test

Figure 17 is a management system for voice information protection equipment for smart offices, which monitors the status of the equipment, the normal operation of the vibrator and speaker in real time, and has been developed so that the administrator can easily control each function. In addition, it is proposed to enable continuous monitoring by collecting and controlling information on connection, failure, and change of equipment.

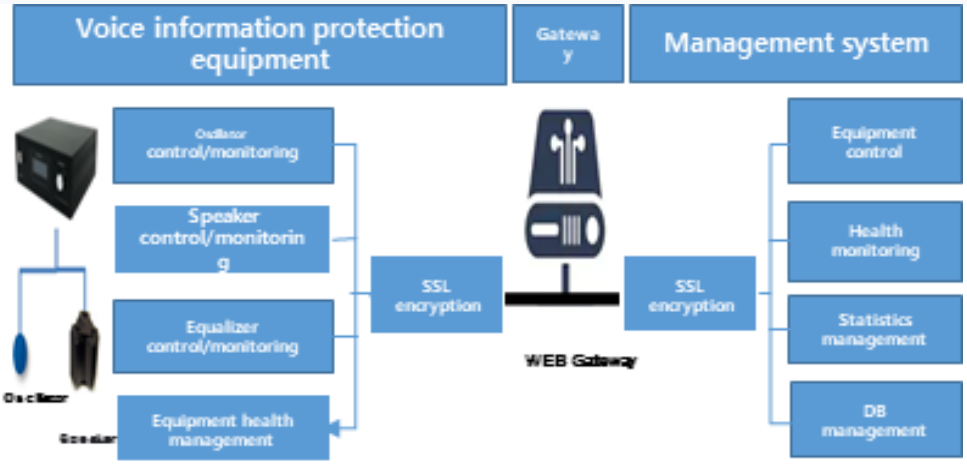

Figure 17. Management system function diagram

5. Conclusion

An algorithm was developed to prevent recording and leakage in real time when a person's

conversation contents are recorded in a smart office environment or when an attempt is made to eavesdrop through an external eavesdropping device. The proposed algorithm requires real-time control of the user as it operates several equipments in one institution. Developed voice information protection equipment and a management system to monitor and control the operation status of the equipment from a remote location.

In this study, as a management system application for voice recording prevention, it is possible to measure the sound pressure level of all frequency components within the range of the voice frequency 20Hz ~ 200KHz. The system design was completed after analysis of the IC parts necessary for the development of the voice leakage prevention vibrator output strength and alarm alarm processing time in case of failure, equipment function, performance structure analysis, operation environment review and analysis.

Through this system, it is possible to output an alarm function, an alarm function, equipment operation status, error-related status, and report when a failure occurs. In addition, by supporting the recording prevention function and the monitoring function of the speaker and the voice leakage prevention vibrator, social conflicts about voice recording can be resolved.

6. Acknowledgments

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7. References

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